SAND PINE ROOT DISEASE SURVEY: FLORIDA - 1980

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ABSTRACT

Sixty thousand sand pines in 200 stands distributed across north and central Florida were examined in 1979 for symptoms of root disease. Overall disease incidence, based on the occurrence of aboveground symptoms, amounted to ca. 4.5% of the trees examined. However, incidence varied with stand type (plantation vs. natural), stand age, and host variety (Ocala vs. Choctawhatchee sand pines) reaching a high of 42% in one Ocala sand pine plantation. Six known or suspected root disease fungi were isolated from roots of diseased trees. *Phytophthora cinnamomi* was the most frequently isolated pathogen from plantation trees and was not isolated from trees in natural stands. *Inonotus circinatus* was the most frequently isolated pathogen from trees > 20 years of age. *Armillariella tabescens* and a fungus tentatively indentified as *Verticicladiella procera* were isolated frequently, but did not appear to be primary etiological factors. *Heterobasidion annosum* and *Phaeolus schweinitzii* were isolated only rarely. Based on projected growth and volume losses for trees ≥ 4" in dbh which succumbed to sand pine root disease in 1979, the statewide impact of sand pine root disease was estimated at $1.5 - 2.5 million annually. The majority of the impact is being sustained within the more extensive Ocala sand pine resource.

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Sand pine, Pinus clausa (Chapm.) Vasey, is receiving increased attention as a valuable forest resource in the southeastern United States. A native of Florida's sandhills, this species is particularly well adapted for growth on sites characterized by deep, infertile, acid, droughty sands; sites on which other commercially important tree species often develop poorly, if at all. Several million acres of land in the Southeast are currently classified as "sandhills", with some 2 million acres occurring in Florida alone (Fig. 1). Sand pine represents a viable option to forest managers through which these lands can be made productive. Today, many forest industries, as well as private landowners are converting large acreages of undesirable sandhill ("scrub") vegetation (Quercus laevis Walt., Q. incana Batr. Q. stellata var. margaretta (Ashe) Sarg., Diospyros virginiana L., and Aristida stricta Michz.) and stagnant, unproductive, slash pine (P. elliottii Engelm.) plantations to plantations of sand pine. Most of these plantations are established with pulpwood or sawtimber as end products in mind. However, interest in sand pine for such products as Christmas trees and "energy wood" is increasing. To satisfy current demand for sand pine planting stock, commercial forest nurseries in Florida are now producing more than 10 million seedlings annually.

"Mushroom root rot", caused by Armillariella tabescens (Scop. ex Fr.) Singer (= Clitocybe tabescens Bres.), has been considered the most important disease, indeed the primary factor, limiting the successful management of sand pine, especially the Ocala variety, P. clausa var. clausa Ward (Balmer 1973, Ross 1973). In recent years, however, we developed an interest in the apparently widespread occurrence of root disease(s) on sand pine which we could not attribute to A. tabescens. Accordingly, and in response to the need for an assessment of the magnitude of the problem, we conducted a survey of sand pine root disease throughout the northern two-thirds of the state of Florida. Our objectives were to 1) determine the distribution of sand pine root disease in Florida 2) identify the known and/or suspected pathogens involved, 3) provide an estimate of the statewide economic impact of sand pine root disease 4) evaluate relationships of host age and variety (Ocala vs. Choctawhatchee = P. clausa var. immuginata Ward), site, and stand type to root disease, and 5) identify aspects of sand pine root disease in need of further research. Our findings are reported herein.

MATERIALS & METHODS

Field Procedures. A ratio estimation method (Yandle & Roth 1971) was employed as the basic sampling procedure for this survey. Highways, including both improved and unimproved state and federal roads north of a line from Tampa to Melbourne were charted, and a survey route of more than 2000 miles was superimposed. A minimum interval of 5 miles between stands was established, taking into account urban centers, private or other nonaccessible areas, and areas suspected of being devoid of sand pine, to provide a potential 400 survey stands. Due to areas where the interval between stands would naturally exceed 5 miles, the 400 stand figure was recognized only as a maximum, not an anticipated total. As the survey progressed, it became clear that the discontinuity of the sand pine resource rendered this approach inadequate. As a result, the minimum interval between stands was reduced to 2.5 miles, and additional survey stands were identified from maps supplied by timber companies, private landowners, and county foresters. In all, a total of 200 natural and planted stands of sand pine were visited and evaluated for root disease.

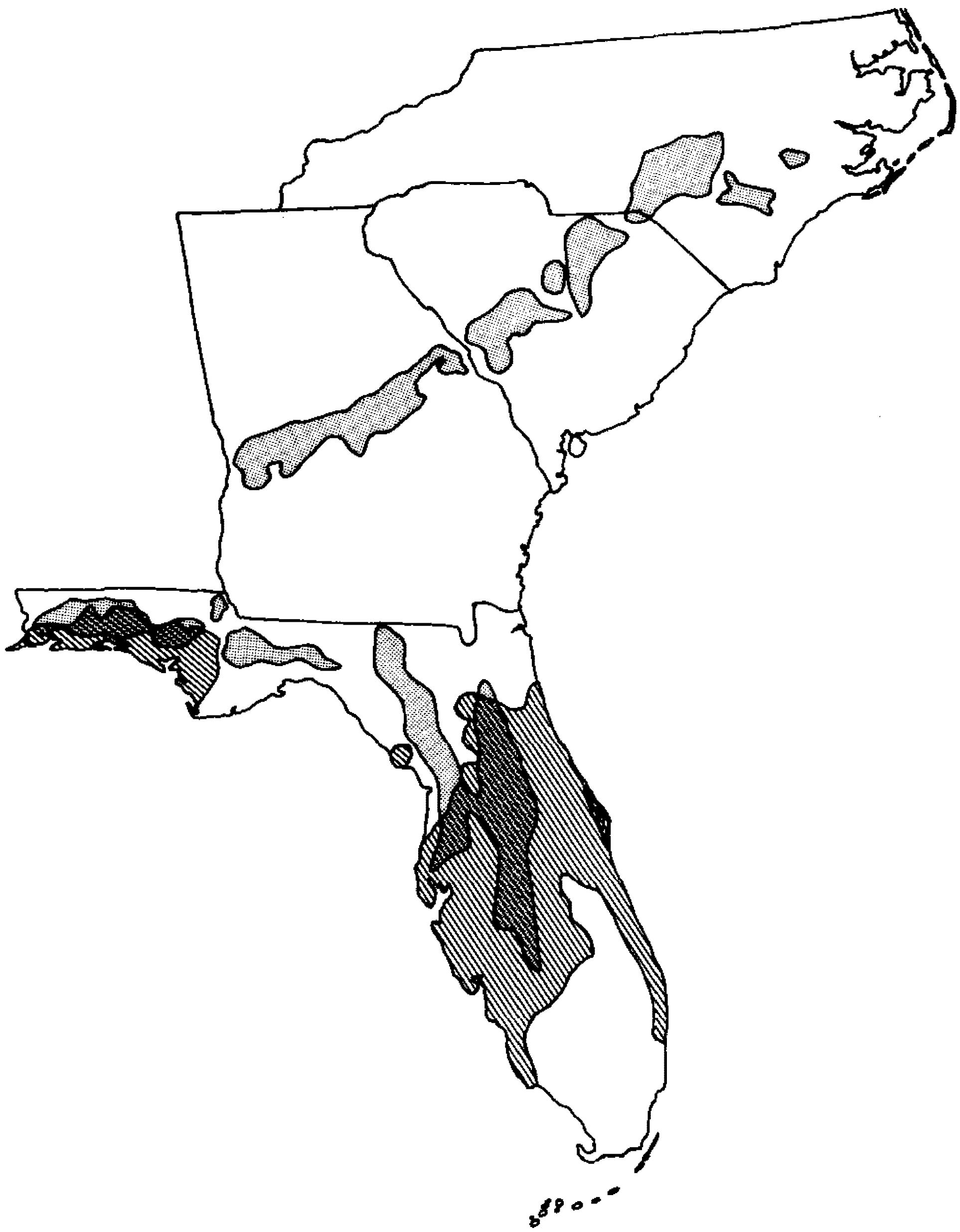


Fig. 1. Distribution of sandhills (shaded) in the southeastern United States and natural range of sand pine (crosshatched).

Only stands meeting certain basic criteria were included in the survey. Specifically, survey stands had to be at least 5 acres in size and free from obvious, artificial stresses (construction damage, etc.). No set maximum stand size was defined, but natural and/or manmade breaks (roads, power lines, drainages, etc.) were utilized as stand boundaries. Stands less than 15 years of age were included only if they contained 250 or more trees per acre and stands 15 years old or older were required to have a minimum basal area of 50 sq. ft. per acre. Decisions as to whether or not individual stands met these criteria were made by preliminary stand reconnaissance and stem counts on each of three 1/40th acre plots or basal area tallies at each of three points located at linear intervals of 12 chains (1 chain = 66') within the stand.

Three transect lines, perpendicular to a convenient base line (stand border, road, fence, etc.), were established in each survey stand. In smaller stands, transects were located at points 1/4, 1/2, and 3/4 of the baseline distance from one side of the stand to the other. In larger stands, baselines were divided into 1/20th-mile or 4-chain intervals which were numbered consecutively, and transects were subsequently selected with a random number table. In planted stands, transects were established parallel to plantation rows, and the row nearest each transect was employed as a sampling base. In natural or seeded stands, trees within 4 or 8' on either side (depending upon stand density) of the transect lines were included in the transect sample. Beginning a minimum of one chain in from the edge of the stand, the first 100 trees along each transect were examined for evidence of root disease. Records were made with respect to the factors indicated in Table 1, and the length and width of each transect was recorded. Stand composition (i.e., Choctawhatchee, Ocala, or mixed varieties) was recorded, and stand age was estimated by averaging ring counts on increment cores taken at breast height from three representative trees within the stand; one from each of the three transect lines. Soil profile irregularities (impervious horizons, mottling, etc.) were examined to a depth of 6' with a 4" bucket auger, one soil core being taken at the midpoint of each of the three transect lines.

Table 1. Factors evaluated on sample trees in a survey of sand pine root disease in Florida.

Factor	Rating Categories
Tree Condition	a) live b) dead - survey year c) dead - previous year
Crown Condition	a) full/thin b) green/discolored c) suppressed/nonsuppressed
Tree Size	a) diameter breast height (inches)[1]
Basal Symptoms	a) cankers (+/) b) root sprung (+/) c) exterior resinosis (+/) d) subcortical resinosis (+/)[2]
Signs (sporocarps, etc.)	a) present/absent (collected & identified)

[1]Not determined for very small trees.
[2]Confirmed on "suspect" trees by removing bark with a small hand axe.

Pathogen Detection. To identify and catalog known and/or suspected pathogens associated with sand pine root disease we revisited nineteen (ca. 10%) of the survey stands for intensive root sampling. Stands were purposely selected which reflected a high incidence of root disease symptoms. In each selected stand we excavated the root systems of three "apparently healthy" and three "obviously diseased" trees (i.e., those with above ground symptoms) and collected root samples representative of the range of symptoms encountered. In the laboratory, we isolated from both asymptomatic and symptomatic root material from apparently healthy trees as well as obviously diseased trees. Ten feeder root segments from each sample tree were plated directly onto a phycomycete-selective medium (PARP: Kannwischer & Mitchell 1981). Chips representative of a variety of discoloration and/or decay patterns, from tap and lateral roots as well as the root collar area, were plated onto each of two different media, i.e., a malt extract agar (MEA = 15 g malt extract + 15 g agar + 1000 ml H_2O) and a basidiomycete-selective medium (OPP = 20 g malt extract + 17 g agar + 100 ppm streptomycin sulfate + 1 ml 50% lactic acid + 2.5 ml of a stock solution of 0.48 g ortho-phenylphenol in 20 ml 95% ethanol + 1000 ml H_2O). Ten individual chip isolations were performed per symptom type within each root category (tap, lateral, etc.) from each sample tree on both of the two media. Isolations were performed in pairs, half of the chips in each case being surface sterilized by alchohol dipping and flaming (95% ethanol), and half being aseptically removed from root samples and plated without surface sterilization. PARP plates were evaluated 3 days following isolation, and MEA and OPP plates were evaluated after an incubation period of one month.

Correction Coefficients. Early in the survey it became clear that many trees which exhibited no aboveground or external symptoms did reveal internal or belowground symptoms upon excavation. As a result, we excavated more than 140 "apparently healthy" trees in 47 natural and planted stands of various ages distributed throughout the survey area, and examined their roots for evidence of root disease (resinosis, etc.). The percentage of apparently healthy trees with internal or belowground symptoms was determined and later utilized to adjust infection levels to better represent the actual root disease situation (ref. Tables 2 and 3).

In a similar vein, many trees recorded on field data sheets as "dead" could not be confidently related to or disassociated from a root disease etiology on the basis of aboveground or external symptoms. Accordingly, more than 130 dead trees and snags in 35 natural and planted stands were excavated and examined for resin impregnation of wood in the tap root, lateral roots and/or root collar. Trees exhibiting this feature were considered victims of root disease, and the proportion of such trees was applied to the field data to better represent mortality due to sand pine root disease (ref. Tables 4, 5 and 6).

Economic Impact Evaluation. The statewide economic impact of sand pine root disease was estimated by assigning cubic foot volumes to each tree 4" or larger in diameter at breast height (dbh) (USFS 1975), projecting the growth of all trees which died in 1979 as a result of sand pine root disease (i.e., current-corrected *sensu* Tables 5 and 6) to rotation age using annual growth rates of 3, 5, and 7%, and discounting the value of projected volumes back to 1979 using discount rates of both 4.0 and 7.125%. The following assumptions and/or resource descriptions were adopted for this analysis.

1. In the absence of root disease, all trees would grow to rotation age at a constant and non-diminishing annual rate (e.g., 3, 5, or 7%).

2. Root disease is a non-random phenomenon and tends to affect trees in "pockets" as opposed to scattered individuals.

3. Current (1979) mortality is representative of "average" annual mortality within each given age class.

4. One cord = 90 cu ft and stumpage values of $23/cord would hold constant for the next 45 years.

5. Rotation ages vary by ownership category and approximate:
   - 30 years - private
   - 50 years - Ocala National Forest (ONF)
   - 40 years - Other federal lands

6. Resource distribution by ownership category and variety approximates:

Variety	Private	ONF	Other Federal
Ocala	45%	42%	13%
Choctawhatchee	66%	0	34%

7. Per acre figures were expanded to a statewide basis according to estimated acreages of each variety in each age class by ownership category. Age class distributions for Choctawhatchee sand pine were calculated on the basis of proportions indicated by the ages of the individual survey stands. In the case of Ocala sand pine, age distributions on the Ocala National Forest were applied to the statewide Ocala sand pine resource.

RESULTS

Root disease was detected in both natural and planted stands of Choctawhatchee sand pine (CSP) as well as Ocala sand pine (OSP). Disease incidence varied with stand type, age, and host variety. Observed disease incidence (ODI, <u>sensu</u> Table 2) within individual plantations ranged from zero to as high as 42% in one OSP plantation. In general, root disease incidence increased with stand age in both varieties, but was notably higher in OSP stands as opposed to CSP stands. Also, the incidence of root disease in young (age = 15 years or less) OSP plantations was decidedly higher than in natural OSP stands of comparable ages (Table 2). Suppressed trees appeared no more susceptible to root disease than dominants and codominants. Observed disease incidence in these two groups average 4.2 and 4.6%, respectively. Although survey data were not definitive, there was an apparent relationship between site factors and severity of root disease. Many badly diseased stands were located on sites characterized by relatively shallow, finer textured soils with poor internal drainage. There were no clear differences in the occurrence of root disease between OSP plantations in central Florida and those in the panhandle area.

Diseased trees, as previously described (Barnard 1979, 1980; Ross 1970), were characterized by varying degrees and combinations of crown thinning and/or discoloration, basal cankering ("flat faces"), basal resinosis, and windthrow or leaning. Internal resin impregnation of roots and root collars was usually a definitive indication of root disease, although this symptom was frequently undetected by the field crew (See Tables 3, 4). Mortality was also common, and root excavations revealed that the majority of sand pine mortality could be attributed to root disease (Tables 4, 5, 6). Of the symptoms considered in this survey (Table 1), subcortical basal resinosis proved to be the single most reliable above ground indicator of root disease. Approximately 80% of the trees with root disease symptoms were found to exhibit this characteristic. Exterior basal resinosis, windthrow, and basal cankers were exhibited by ca. 22, 23, and 16% of the diseased trees, respectively.

Table 2. Observed (ODI)[a] and corrected (CDI)[b] incidence of root disease in Florida sand pine stands by variety, stand type, and age class.

	Plantation				Natural			
	Choctawhatchee		Ocala		Choctawhatchee		Ocala	
Age Class	ODI	CDI	ODI	CDI	ODI	CDI	ODI	CDI
0-5	0.4	0.4	0.8	18.6	0.0	[c]	0.3	13.3
6-10	1.1	1.1	3.0	20.5	1.3	---[c]	0.0	13.0
11-15	0.7	25.5	6.0	30.4	0.0	---[c]	3.7	3.7[d]
16-20	3.6	27.5	1.4	27.0	4.5	---[c]	8.0	8.0[d]
21-25	---	---	---	---	6.9	6.9[d]	4.1	35.8
26-30	---	---	---	---	5.2	5.2[d]	8.3	38.5
31-35	---	---	---	---	5.0	55.4	8.0	89.9
> 35	---	---	8.3	---[c]	8.6	57.0	15.8	90.7

[a]ODI = per cent of trees exhibiting above ground or external symptoms.

[b]CDI = ODI + appropriate correction coefficient (i.e., % "apparently healthy" trees exhibiting below ground or internal symptoms such as resinosis, etc., ref. Table 3).

[c]No correction coefficient available (ref. Table 3).

[d]Correction coefficient based only on one stand (ref. Table 3).

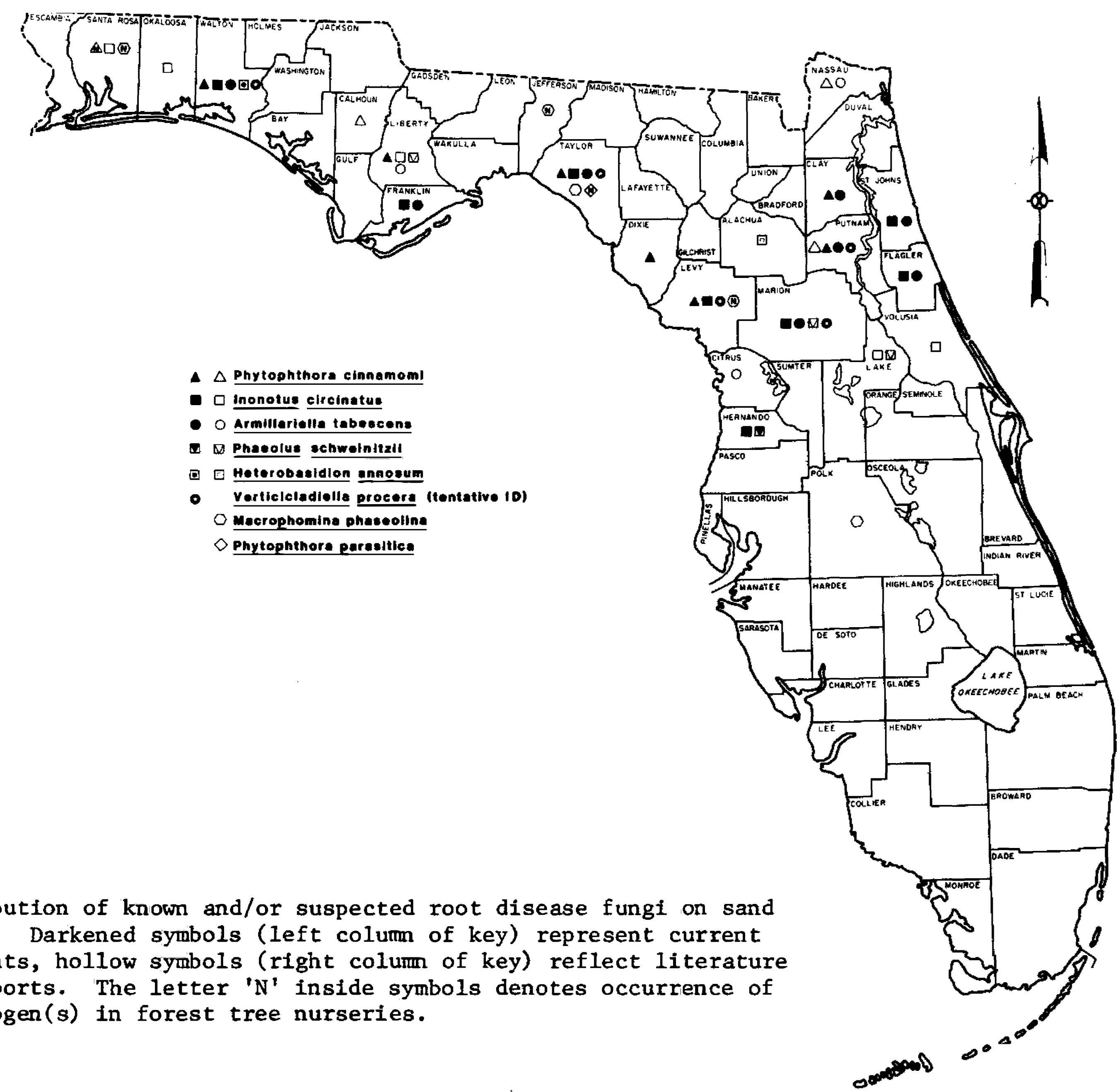


Fig. 2. Distribution of known and/or suspected root disease fungi on sand pine in Florida. Darkened symbols (left column of key) represent current survey data points, hollow symbols (right column of key) reflect literature and/or other reports. The letter 'N' inside symbols denotes occurrence of respective pathogen(s) in forest tree nurseries.

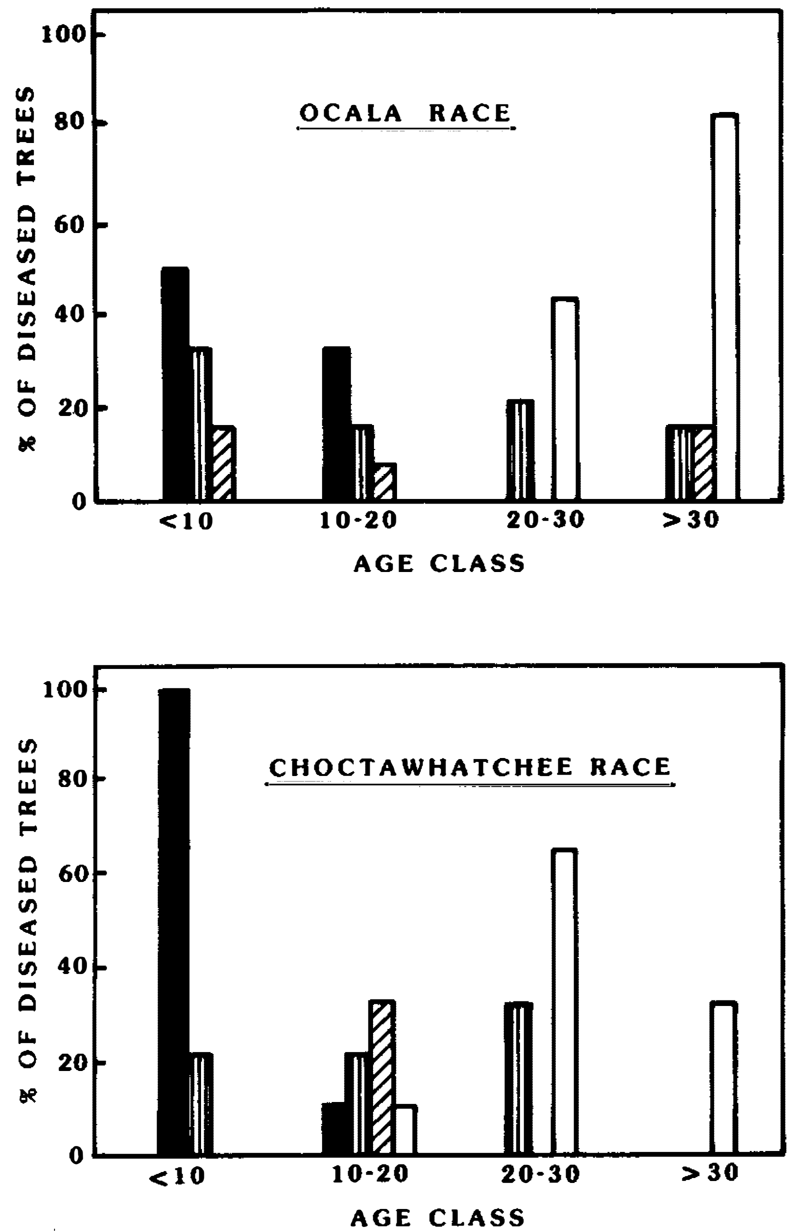
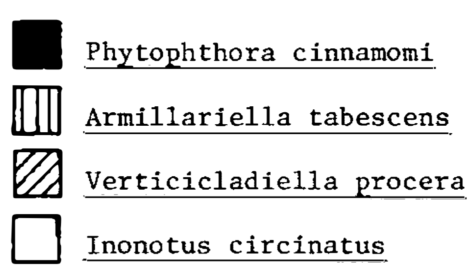


Fig. 3. Percentage of diseased Choctawhatchee and Ocala variety (race) sand pines yielding various root pathogens (known and/or suspected) upon isolation. Trees < 10 and 10-20 years of age from plantations, trees 20-30 and > 30 years of age from natural stands.



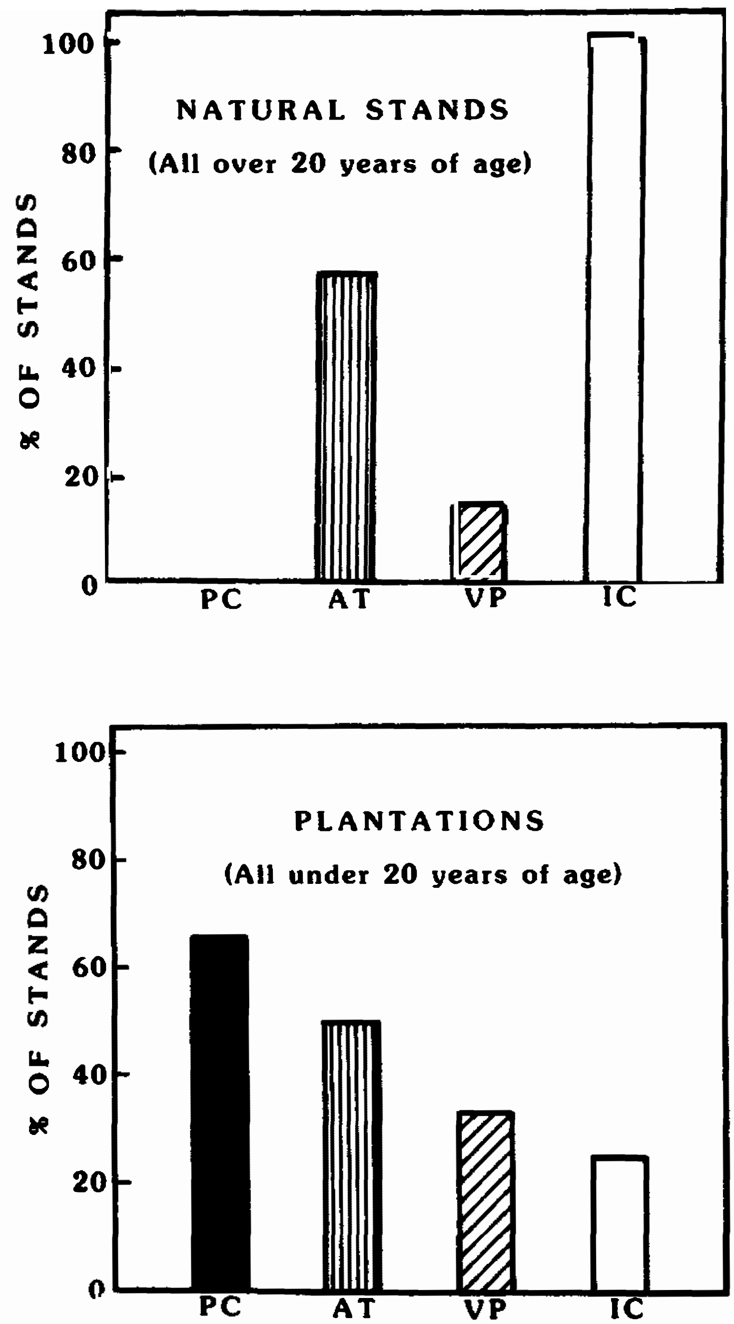


Fig. 4. Percentage of diseased sand pines in natural stands and plantations yielding various root pathogens (known and/or suspected) upon isolation.

PC = *Phytophthora cinnamomi*

AT = *Armillariella tabescens*

VP = *Verticicladiella procera*

IC = *Inonotus circinatus*

Several known and/or suspected root disease fungi were isolated from roots of sand pine during the course of this survey (Table 7). Occurrence of these fungi was widespread (Fig 2), and in no case did any of the fungi exhibit definitive varietal preferences (OSP vs. CSP, Figs. 3 and 4). Patterns of occurrence were apparent, however, with respect to stand type and stand age (Figs. 3 and 4). Other patterns were evident also in terms of a) what kinds of root material (resin soaked, water soaked, etc.) yielded which fungus (Table 7), and b) the relative frequencies of occurrence of the various fungi (Figs. 3 and 4). *Phytophthora cinnamomi* Rands and *Inonotus circinatus* (Fries) Gilbertson were the most frequently recovered root pathogens, *P. cinnamomi* being dominant in younger, planted stands (ca. $\leq$ 15 years of age) and *I. circinatus* predominating in older stands (ca. 15 years of age and older). In no case was *P. cinnamomi* isolated from trees in natural stands (artificially seeded stands included in this category). *Armillariella tabescens* and *Verticicladiella procera* Kendrick (tentative identification - pathogenicity uncertain) were isolated with moderate regularity while *Phaeolus schweinitzii* (Fr.) Pat. and *Heterobasidion annosum* (Fr.) Bref. were isolated only occasionally (Figs. 2, 3 and 4). Occurrence of two or more of these six fungi on the same tree was common (Fig. 5).

The estimated economic impact of root disease on Florida's sand pine resource was substantial, ranging from $1.5 to 2.5 million annually (Table 8), the relative impact being greater in the more extensive OSP resource.

Table 3. Percent "apparently healthy" sand pine trees exhibiting belowground or internal evidence (resinosis, etc.) of root disease.[a]

	Choctawhatchee			Ocala		
Age Class	Plantation	Natural Stands	Mean	Plantation	Natural Stands	Mean
0-10	0(5)	---	0(5)	18(9)	13(5)	16(14)
11-20	25(4)	---	25(4)	26(9)	0(1)	23(10)
21-30	---	0(1)	0(1)	---	33(5)	33(5)
> 30	---	53(1)	53(5)	---	89(3)	89(3)

[a]weighted means based on number of stands indicated in parentheses (minimum of four trees examined per stand).

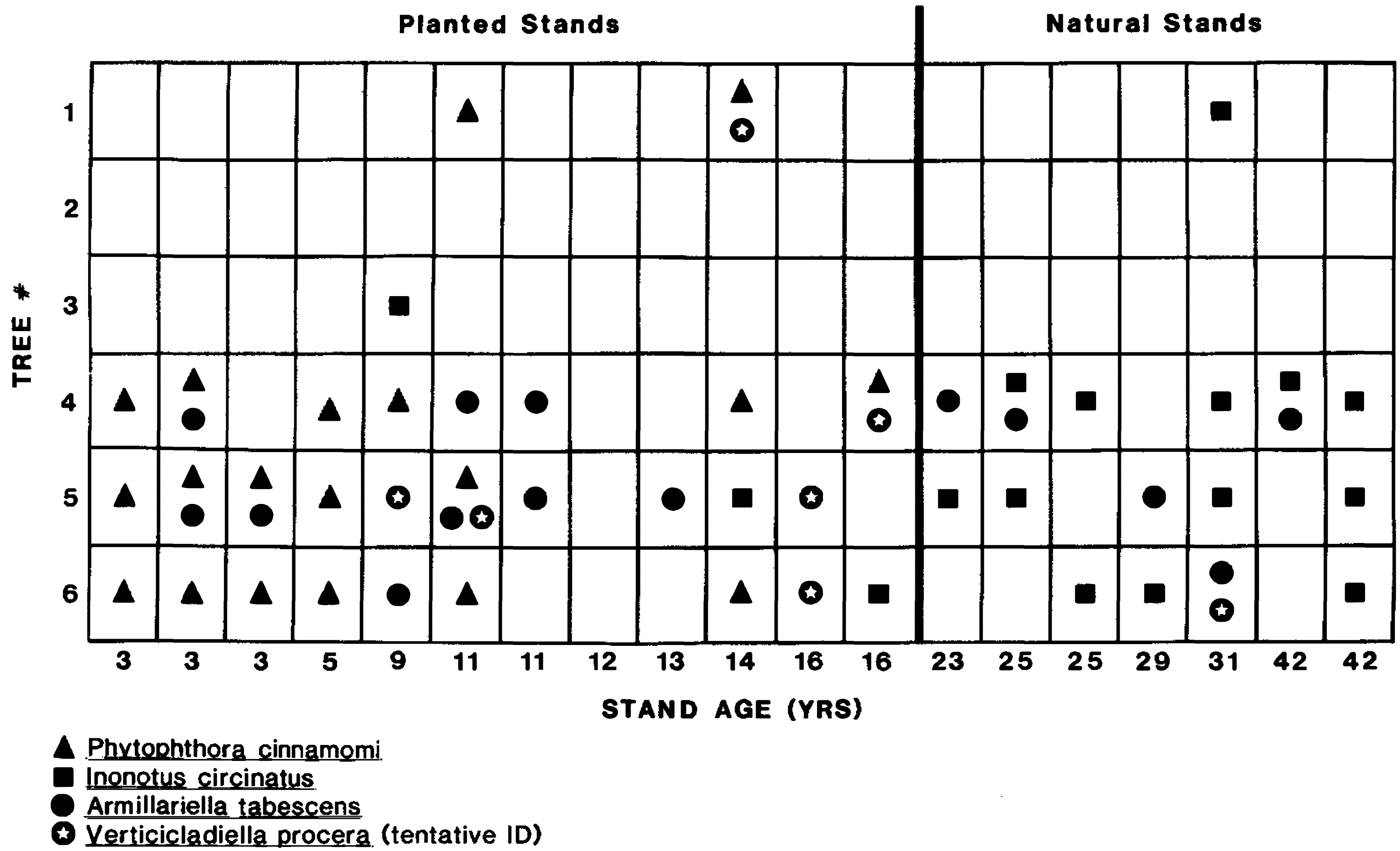


Fig. 5. Summary of pathogens recovered from individual sample trees in diseased sand pine stands in Florida. Trees #1-3 - asymptomatic, presumably healthy. Trees #4-6 - symptomatic for root disease. Vertical columns of squares represent six individual trees sampled from each of 19 selected stands (ages of individual stands depicted at column bases).

Table 4. Percentage of dead trees originally not attributed to sand pine root disease which exhibited below-ground or internal evidence (resin impregnation, etc.) of root disease.[a]

Age Class	Choctawhatchee Plantation	Choctawhatchee Natural Stands	Choctawhatchee Mean	Ocala Plantation	Ocala Natural Stands	Ocala Mean
0–10	100(2)	---	100(2)	77(6)	---	77(6)
11–20	83(3)	75(1)	81(4)	92(3)	100(1)	94(4)
21–30	---	83(3)	83(3)	---	94(4)	94(4)
> 30	---	86(6)	86(6)	---	82(6)	82(6)

NOTE: Overall correction factor employed in analyses (ref. Tables 5 and 6) = 75%.

[a] Weighted means based on number of stands indicated in parentheses (minimum of four trees examined per stand).

Table 5. Mortality analysis for stands of Choctawhatchee sand pine suffering from sand pine root disease (SPRD) in Florida.

		All Mortality (Trees/acre)		SPRD Mortality (Trees/acre)			
				Uncorrected[a]		Corrected[b]	
Age Class	Avg. No. Trees/acre	Current[c]	Total[d]	Current	Total	Current	Total
PLANTATIONS							
0-5	516	1.47	1.97	.86	1.35	1.32	1.82
6-10	570	2.06	5.38	.95	3.17	1.78	4.83
11-15	649	4.33	12.13	.43	2.17	3.35	9.64
16-20	703	3.13	21.89	.78	10.16	2.54	18.96
NATURAL STANDS							
0-5	1631	5.44	5.44	0	0	5.44	5.44
6-10	1896	0	50.57	0	0	0	37.93
11-15	1373	0	20.59	0	0	0	15.44
16-20	631	3.16	28.40	2.10	13.67	2.90	24.72
21-25	639	45.44	74.56	18.46	27.69	38.70	62.84
26-30	658	4.08	54.56	.63	12.23	3.22	43.98
31-35	657	14.51	81.05	0	18.07	10.88	65.30
35	625	11.63	107.28	2.76	29.07	9.41	87.73

[a]As recorded by field crew based on readily observed above ground symptoms.

[b]Adjusted to include 75% of all dead trees not originally assigned to SPRD (ref. Table 4).

[c]1979 mortality.

[d]Cumulative mortality.

Table 6. Mortality analysis for stands of Ocala sand pine suffering from sand pine root disease (SPRD) in Florida.

		All Mortality (Trees/acre)		SPRD Mortality (Trees/acre)			
				Uncorrected[a]		Corrected[b]	
Age Class	Avg. No. Trees/acre	Current[c]	Total[d]	Current	Total	Current	Total
			PLANTATIONS				
0–5	437	2.33	3.20	1.16	2.04	2.04	2.91
6–10	506	2.40	12.61	.89	5.60	2.02	10.86
11–15	502	3.34	21.82	1.43	11.94	2.86	19.35
16–20	534	3.22	23.62	.72	2.86	2.60	18.43
—	—	—	—	—	—	—	—
35	372	1.24	37.20	1.24	14.88	1.24	31.62
			NATURAL STANDS				
0–5	1070	3.57	3.57	3.57	3.57	3.57	3.57
6–10	832	0	0	0	0	0	0
11–15	1046	45.34	64.18	19.53	26.16	38.89	54.68
16–20	644	52.72	107.27	11.03	30.96	42.30	88.19
21–25	714	54.63	123.26	6.86	18.12	42.69	96.98
26–30	523	44.45	101.57	10.06	26.75	35.85	82.86
31–35	656	53.55	142.61	13.66	37.15	43.58	116.24
35	493	44.06	134.49	24.76	60.34	39.24	115.95

[a] As recorded by field crew based on readily observed above-ground symptoms.

[b] Adjusted to include 75% of all dead trees not originally assigned to SPRD (ref. Table 4).

[c] 1979 mortality.

[d] Cumulative mortality.

Table 7. Known and/or suspected root pathogenic fungi isolated from roots of sand pine in Florida.

	Root Material	
Fungus	Type[a]	Condition[b]
Armillariella tabescens	T,L	WS*,RS,D,WPR
Heterobasidion annosum	L	A
Inonotus circinatus	T,L,RC	RS*,WPR*,S*
Phaeolus schweinitzii	T	RS
Phytophthora cinnamomi	F	N,RS
Verticicladiella procera[c]	T,L,RC	RS*
	Non-Survey Reports	
Phytophthora parasitica	F	N
Macrophomina phaseolina	T,L,F	N

[a]T = tap root, L = lateral root, F = feeder root, RC = root collar.

[b]RS = resin soaked, WS = water-soaked, N = necrotic, S = stained, A = asymptomatic, WPR = white pocket rot, D = dry sound wood.

[c]Tentative Identification.

*Primary symptom type yielding fungus indicated.

Table 8. Analysis of estimated statewide impact (mortality only) of sand pine root disease (SPRD) in Florida (dollar value of annual timber losses).

		Discount Rate					
		7.125% Tree Growth			4.0% Tree Growth		
Age Class	Acres	3%	5%	7%	3%	5%	7%
CHOCTAWHATCHEE SAND PINE							
0-5	36,517	0	0	0	0	0	0
6-10	31,233	0	0	0	0	0	0
11-15	26,083	3,026	4,252	5,999	5,138	7,329	10,433
16-20	34,778	40,099	51,263	65,696	58,705	75,955	98,630
21-25	6,940	23,270	27,024	31,528	29,384	34,533	40,807
26-30	13,911	28,212	29,756	31,592	30,715	32,715	35,250
31-35	12,172	0	0	0	0	0	0
> 35	39,994	103,424	103,424	103,424	103,424	103,424	103,424
Total	201,628	198,031	242,719	238,239	227,366	254,029	288,544
OCALA SAND PINE							
0-5	64,919	0	0	0	0	0	0
6-10	64,919	3,311	5,583	9,608	7,531	13,308	24,020
11-15	20,287	7,324	11,219	17,589	14,302	32,005	37,815
16-20	20,287	26,799	37,328	53,193	45,179	165,994	98,717
21-25	16,236	23,477	29,679	38,512	34,128	45,266	61,616
26-30	16,236	41,158	47,279	55,803	51,582	62,168	76,991
31-35	16,236	14,694	18,054	22,308	20,263	25,263	31,595
> 35	186,642	1,343,449	1,500,415	1,686,684	1,598,589	1,809,494	1,059,968
Total	405,762	1,460,212	1,649,557	1,883,697	1,771,574	2,144,498	2,390,722
GRAND TOTAL	607,390	1,658,243	1,892,276	2,121,936	1,998,940	2,398,527	2,679,266

DISCUSSION

Results of this survey document a sand pine root disease problem of considerable magnitude in Florida. It is clear that this problem is a function of a variety of factors, including not less than eight known and/or suspected root disease fungi*. The specific roles of these fungi in sand pine root disease are not fully understood, although some implications may be drawn from the survey data. For example, it appears that I. circinatus plays a dominant role in older age trees, but is much less a factor in young trees. On the other hand, P. cinnamomi would appear to be the major, and perhaps most important, pathogen in young plantations (Figs. 3, 4, and 5).

The infrequent recoveries of H. annosum and P. schweinitzii tend to reflect an "incidental" character for these pathogens in the sand pine root disease complex. Caution is advised, however, before broadly applying this label as damages attributable to these fungi could become important in certain situations (stand thinnings, overmature timber, unfavorable sites, etc.).

The intermediate levels of recovery of A. tabescens and V. procera (tentative ID) are somewhat more difficult to interpret. Undoubtedly, these fungi should be considered as participants in the root disease complex, but detailed research will be required to elucidate their particular functions and significance. At this time, it appears probable that neither of these fungi plays a dominant role in the sand pine root disease complex. In fact, in 50% or more of the trees from which these fungi were recovered, at least one other known or suspected root disease fungus was recovered as well (Fig. 5), thus suggesting an "opportunist" habit as opposed to that of a primary or aggressive pathogen. In many cases A. tabescens was isolated from distal, dead and water-soaked roots (Table 7) which appeared to have been previously "cut-off" from the tree by resin soaking apparently induced by either P. cinnamomi or I. circinatus. Rarely was A. tabescens isolated from resin-soaked roots, the primary symptomatic root type associated with sand pine root disease. Given the well documented "opportunistic" or "secondary" nature of Armillariella mellea (Fr.) Karst. (Armillaria mellea Fries), a generic relative, it is not difficult to postulate such a role for A. tabescens.

Verticicladiella procera and Inonotus cirinatus have not heretofore been reported to occur on sand pine. V. procera is known to be involved in the white pine (Pinus strobus L.) root decline problem in the northeastern U. S. as well as a root malady of red pine (P. resinosa Ait.) in New York (Sinclair and Hudler 1980, Swai 1980, Towers 1977). V. wagenerii Kendrick, a closely related species, is a known root pathogen on a variety of conifers in the

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*Although not recovered during the formal execution of this survey, both Macrophomina phaseolina (Tassi) Goid. and Phytophthora parasitica Dast. should be considered in the sand pine root disease picture. Both pathogens have been detected on the roots of diseased sand pines in Florida (Florida Division of Plant Industry files - ref. Fig. 2 and Table 7). M. phaseolina has also been repeatedly detected in diseased sand pine plantations in Georgia as well (S. W. Oak - U.S.F.S., S.A. S & PF - personal communication).

western U. S. (Smith 1979, Cobb and Platt 1967, Smith 1967). Inonotus circinatus (= Polyporus tomentosus var circinatus Fr. Sartory & Maire) is a well known root disease pathogen on a variety of conifers in North America (Patton and Myren 1970, Whitney 1977) and is known to act as a root pathogen on slash pine (P. elliottii Engelm.) in association with basal fusiform rust cankers (Boyce 1963, 1965, 1967, Ross 1966). Much work is needed to clarify the etiological and/or epidemiological roles of these fungi, as well as the specific roles of the other pathogens detected in the sand pine root disease complex.

The fact that we did not recover P. cinnamomi from natural stands is compatible with previously published data (Ross 1973, Ross and Marx 1972) and raises questions as to the origin of this pathogen in planted stands (plantations, seed orchards, etc.). Given that P. cinnamomi is, in all probability, an introduced pathogen, and that it is a known forest tree nursery pathogen (Barnard 1980, Kuhlman and Smith 1975), it is possible that this fungus has been introduced into many planting sites via infected nursery stock. Other modes of entry may have been involved as well (the hooves of both domestic and wild animals, overland soil and water movement, etc.), but one which should not go unmentioned is the possibility of introduction via contaminated site preparation and planting equipment which was previously operating in Phytophthora-infested areas (seed orchards, nurseries, littleleaf disease sites, etc.). Recognition and regulation of these potential modes of entry, as well as the delineation of the current distribution of P. cinnamomi on sand hill sites could be key elements in a preventive strategy for minimizing the future impact of sand pine root disease.

During the survey, stands were selected for root isolations on the basis of the occurrence of aboveground root disease symptoms (Table 1) recorded on field data sheets. Accordingly, isolations were purposefully allocated to stands having higher levels of "apparent" root disease. As a result, one inherent weakness in our data is that no isolations were performed from roots of trees in natural stands less than 20 years of age (Figs. 3 and 4). Clearly, isolations from young natural stands are needed to further clarify critical aspects of the etiology and epidemiology of sand pine root disease. The scarcity of sand pine plantations greater than 20 years of age accounts for the lack of data within this category. (Ref. Tables 2-6 and Figs. 3-5).

In general, our soil characterizations were inadequate to draw any rigid conclusions regarding what does or does not constitute a high hazard site for sand pine root disease. Overall, we observed nothing that would immediately or strongly modify the observations of others (Ross 1970, Ross and Marx 1972). By and large, plantation sites characterized by finer textured, poorly drained soils or those having shallow (< 6') impervious layers or evidence of poor drainage/aeration (mottling, etc.) appeared to be more conducive to root disease development. It is noteworthy that these are the types of soils which are usually regarded as favored habitat for fungi of the water mold type - including P. cinnamomi. In natural stands, disease/site relationships were not readily apparent, and other factors seemed to be more important (e.g., the apparent absence of P. cinnamomi and the increasing occurrence of I. circinatus with increasing stand age, Figs. 3, 4, and 5).

The complexity of factors involved in sand pine root disease raises questions as to why CSP apparently suffers less damage from root disease in the field than OSP. This has been referred to as resistance (Brendemuehl 1981) on the part of CSP, but in fact such resistance is without substantive pathological documentation. For example, Ross and Marx (1972) reported that CSP was nearly twice as susceptible to *P. cinnamomi* than was OSP, implying relative resistance on the part of the latter. To date, little emperical data exist on the relative susceptibility and/or resistance of OSP and CSP to the other putative root pathogens involved in the disease syndrome. Ross (1973) futher reported a higher incidence of *P. cinnamomi* in OPS plantations (4 of 8 or 50% of sampled plantations positive, avg. propagules/g soil = 2.7) as opposed to CSP plantations (1 of 4 or 25% of sampled plantations positive, avg. propagules/g soil = 0.6). These data, considered in the light of the "introduced" status of *P. cinnamomi* and its apparent absence from natural stands, raise the distinct possibility of disease escape, at least insofar as this important pathogen is concerned. Meaningful evaluations of resistance on the part of CSP and OSP to specific disease organisms should be based on carefully conducted pathological experiments so as to guarantee equivalent exposures to the pathogen(s) in question. In the same vein, comparative field plantings of these two sand pine varieties should be based on seedlings from the same nursery, so as to provide equal opportunity for the possible introduction of *P. cinnamomi* on planting stock. Comparisons of random field plantings from different nurseries and different years do not account for this latter, potentially significant variable.

Although impressive, the estimated statewide impact of sand pine root disease amounting to $1.5 - 2.5 million per year (Table 8) is not considered an overestimate. No attempt was made to include losses resulting from reduced growth of diseased trees or morality of trees < 4" in dbh at the time of the survey, reestablishment costs for plantations replanted before merchantability due to root disease, or losses in high value nurseries or seed orchards. Losses in one Florida seed orchard alone have been conservatively estimated to exceed $500,000 and at least two other seed orchards in the state are now experiencing losses to this disease complex as well. In addition, restricting sample stands to those having minimum stocking levels (ref. Materials and Methods) may have resulted in the overlooking altogether of stands which were sparingly stocked as a result of sand pine root disease. It should be noted, however, that the major portion of the overall impact reflected in Table 8 is being sustained in the Ocala National Forest as a result of the heavy concentration of older, larger trees therein (Oak *et al.* 1981).

RECOMMENDATIONS

I. Control

Based on our current knowledge of the sand pine root disease complex, several general recommendations for prevention and control can be made.

A. Site Selection & Species Alternatives

Be especially careful in selecting sites for sand pine plantations. Avoid areas with finer textured, shallow, or poorly drained soils. Replanting sand pine on sites from which diseased sand pine plantations have been removed could be risky, particularly where *P. cinnamomi* is involved. The use of alternative species should be considered when dealing with marginal sites or sites from which diseased stands have been removed.

B. Site Preparation

Although little is known regarding the possibility of site contamination with *P. cinnamomi* on site preparation (and planting) equipment, some cautions are advised. Avoid movement of uncleaned equipment from known *P. cinnamomi*-infected areas (littleleaf disease sites, diseased sand pine stands, etc.) onto previously disease-free areas. Site contamination is a possible source of diseased stands and is often not given the consideration it deserves.

C. Disease-Free Planting Stock

Be sure planting stock is free of *Phytophthora cinnamomi*. Transplanting this fungal pathogen to the field on the roots of nursery stock may result in serious problems in later years, especially on sites where excessive moisture may be a problem. Careful nursery inspection and appropriate regulatory measures may be applicable here. Avoid, if possible, producing sand pine seedlings in nurseries or seedbeds with known histories of *P. cinnamomi*. Natural regeneration should be considered where feasible, thus minimizing chances for inadvertent introduction of *P. cinnamomi* on planting stock.

D. "Pathological Rotation"

Consider stand rotation ages carefully so as to minimize losses to the apparently ubiquitous *Inonotus circinatus*. This fungus appears to be dominant in older aged trees (> 20 years of age) and is presumably the primary disease - and mortality factor therein. Excessively long stand rotations may increase losses caused by this fungus.

II. Research

Several basic questions regarding the sand pine root disease complex remain. Many of these are critical and need research evaluation in order to maximize our ability to manage sand pine and minimize future losses to root disease. Key questions are listed below.

A. What is the carry over impact of sub-symptomatic, sub-lethal, incipient *P. cinnamomi* infections which originate on sand pine planting stock in forest tree nurseries?

B. How large is the nursery - *P cinnamomi* problem at present? Where are problem nurseries located? Is there a nursery problem?

C. Is *P. cinnamomi* well established in potential sand pine planting sites before site preparations and planting? If so, can this area of establishment be identified by survey, etc., and avoided? Is avoidance necessary?

D. What are good sand pine sites - those which provide growth potential and minimal root disease risk? How can these be practically and easily identified by the forest manager?

E. Will *P. cinnamomi* survive and cause significant losses to sand pine on "good" sand pine sites? Or, is this pathogen only a problem in "off-site" situations? Is *P. cinnamomi* the primary agent of pathogenesis, or does excessive moisture, in an of itself, result in root disease?

F. What is the effect of intra- and interstate movement of site preparation and planting equipment on the movement of *P. cinnamomi*? Is this involved in the overall incidence of sand pine root disease?

G. How long does *P cinnamomi* remain viable on given sites? Can sand pine stands be re-established on diseased sites - when?

H. At what age should mature stands of sand pine be cut to minimize losses to *Inonotus circinatus*? What is the "pathological rotation" on different sites?

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APPENDIX

Prior to and during the course of this survey, considerable interest centered on the overwhelmingly consistent recovery of a previously undescribed Deuteromycete (Sphaeropsidales) from diseased sand pine root tissues. Initially, there was some speculation as to the possible role of this unique fungus in the etiology of sand pine root disease. During the course of the survey we attempted to determine a) whether or not this fungus might be a factor in the sand pine root disease complex, and b) why we recovered same so consistently from diseased root tissue, often to the exclusion of other known or putative root disease fungi. Accordingly, we performed numerous isolations from both diseased and apparently healthy root tissues, as well as from the stemwood of sand pines at breast height and mid-crown. Because of early indications that isolation methodology (i.e., 95% ethanol flame-sterilization of surfaces of plated wood chips) was perhaps influencing our isolation results dramatically, we performed all isolations in pairs — one chip being flamed, the other plated directly with no surface sterilization. Paired isolations were performed on both malt extract agar and ortho-phenylphenol medium (recipes included in materials and methods section).

Throughout the course of our isolations we were able to recover the unidentified Deuteromycete from asymptomatic (apparently healthy) as well as symptomatic (resin-soaked, etc.) root tissues, and from "normal" xylem tissue in the bole of both diseased and healthy sand pines. Perhaps our most interesting find is the fact that we could recover this unique fungus, almost at will, from sand pine wood tissue as long as we alcohol-flame-sterilized the surfaces of plated chips. When flame sterilization was not employed, our recoveries of this organism dropped off dramatically. Table A-1 summarizes our recoveries of four different fungi from diseased sand pine roots by isolation methodology and medium employed on an individual tree basis. Differences in recovery of the unidentified Deuteromycete by isolation methodology were even greater than those depicted in the table when viewed on an individual chip basis. Clearly, these data emphasize the expediency of employing a variety of media and isolation techniques in a survey of this type. Limiting the media and/or isolation methodology employed could have had profound effects on our results.

Table A-1. Percent trees yielding known and/or suspected pathogens by medium and isolation methodology: Sand Pine Root Disease Survey - Florida 1980.

	OPP		MEA	
Pathogen	Flamed	Unflamed	Flamed	Unflamed
Inonotus circinatus	10.5	14.0	8.9	7.8
Armillariella tabescens	4.4	12.2	2.2	3.3
Verticicladiella procera	0	0	1.1	7.8
Unidentified Deuteromycete (Sphaeropsidales)	57.9	27.2	34.4	6.7

To date, the identity and function of the peculiar unidentified Deuteromycete remains unknown. Work is currently under way by the senior author, in cooperation with Dr. James W. Kimbrough of the University of Florida, to describe and name this organism. Limited inoculation trails have failed to demonstrate pathogenicity, a result which is compatible with the apparently common existence of the fungus in healthy as well as diseased trees.

Forestry Bulletin SA-FB/P 12 October 1979

Pest Alert

FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
IN COOPERATION WITH YOUR STATE AGENCY

RESIN-SOAKED ROOT DISEASE OF SAND PINE

A root disease is killing sand pines throughout much of the range of this species in Florida. Both the Ocala and Choctawatchee races of the species are affected, although perhaps not equally so. The cause of this disease is uncertain, but several biological and environmental factors are suspected.

Species affected.—Only sand pine is know to be affected.

Symptoms.—The roots and root collar area of affected trees are soaked with resin. Often, resin bleeds through breaks in the bark at the base of trees. Such bleeding may be associated with flat faces or depressions near the ground. Crown thinning and/or discolored foliage are common.

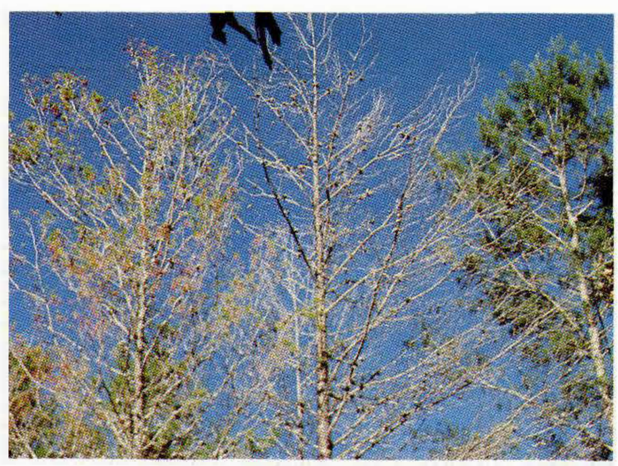
Damage.—Infection centers consist of one to several trees in both natural and artificially regenerated stands. Trees may be windthrown while still alive, or killed outright. As use of this species increases in Florida and other southern States, this disease will become increasingly important.

Resin flow at base of sand pine.

Windthrown sand pine.

Aftermath of the disease.

Root showing resin soaking.



Crown discoloration and thinning.

REPORT DAMAGE TO:

PREPARED BY: E.L. Barnard, Forest Pathologist, Florida Department of Agriculture and Consumer Services, Division of Forestry.

Forest Pest Management
Asheville Field Office

Report #82-1-30
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SAND PINE ROOT DISEASE SURVEY: FLORIDA - 1980

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